Communication

# Valuing energy-saving measures in residential buildings: A choice experiment study

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## ABSTRACT

Air-conditioning and heating energy-saving measures can cut back the usage of energy. This paper attempts to apply a choice experiment in evaluating the consumer's willingness to pay (WTP) for air-conditioning and heating energy-saving measures in Korea's residential buildings. We consider the trade-offs between price and three attributes of energy-saving (window, facade, and ventilation) for selecting a preferred alternative and derive the marginal WTP (MWTP) estimate for each attribute. We also try to test irrelevant alternatives property for the estimation model holds and compare the estimation results of the multinomial logit (MNL) and the nested logit (NL) models. The NL model outperforms the MNL model. The NL model show that MWTPs for increasing the number of glasses and their variety, for increasing the thickness of facade for 1 mm, and for establishing a ventilation system are KRW 17,392 (USD 18.2), 1,112 (1.2), and 11,827 (12.4), respectively. Overall, the potential consumers have significant amount of WTP.

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## 1. Introduction

In Korea where all four seasons are clearly defined, air-conditioning and heating energy are given a great deal of weight on the use of energy. Air-conditioning and heating energy-saving measures can cut back the usage of energy and can cause to be a positive influence on the environment and the problems of global warming. However, there have been no studies about energy-saving measures in residential buildings of Korea, though there have been many studies for other countries. For example, Cameron (1985) analyzed the demand for energy-efficiency retrofits such as insulation and storm windows using the actual data collected by a national survey on energy consumption. Sadler (2003) used a choice experiment (CE) to investigate the preferences of residential consumers in Canada when making investment decisions regarding heating system or a renovation that affects the efficiency of home energy consumption. Banfi et al. (2008) also used CE and focused on the benefits of energy-saving attributes valued by the Switzerland consumers. In addition, there exist similar energy policy applications in the region such as Nomura and Akai (2004) or previous CE valuation studies in a related area like urban air pollution (Yoo et al., 2008).

At the field of residential energy efficiency in Korea, there have been no special efforts to improve the energy-efficiency status. However, people become interested in these days. Therefore, the purpose of this paper is to apply a CE in evaluating the consumer's willingness to pay (WTP) for air-conditioning and heating energy-saving measures in Korea's residential buildings. As CE reflects consumers' preferences among energy-saving measures, the efficiency of energy policy can be enhanced using the results of this research. We consider the trade-offs between prices and attributes of energy-saving measures (window, insulating material, and ventilation) for selecting a preferred alternative and derive the marginal WTP (MWTP) estimate for each attribute. The CE is a suitable method for valuing environmental goods with multi-attributes (Garrod and Willis, 1997; Baarsma, 2003). Especially, it is easier than other valuation methods in estimating the value of each attribute that makes up a target good. Moreover, it allows respondents to systematically evaluate trade-offs among multiple environmental attributes or among environmental and non-environmental attributes (Johnson and Desvousges, 1997).

## 2. Methodological issues

### 2.1. Objects to be valued and attributes

To identify the important attributes of energy-saving measures, we selected a preliminary set of attributes that was derived by extensive literature reviews. Then, we reviewed and

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**Table 1**
Attributes and levels of air-conditioning and heating energy-saving measures.

| Attributes | Descriptions | Levels |
|---|---|---|
| Window | The type of window located outside the residential buildings | 18 mm double glazing<br>24 mm system glazing<br>Double-sash system |
| Façade | The level of facade used inside the outer wall of residential buildings | Present level<br>5 mm thicker than now<br>10 mm thicker than now |
| Ventilation system | The establishment of ventilation system | Yes<br>No |
| Price | Willingness to pay for energy-saving measures through additional costs of interior per 3.3 m² | KRW 80,000<br>KRW 150,000<br>KRW 250,000<br>KRW 400,000 |

revised them through interviews with some experts. The final attributes were selected based on the three criteria such as: the attributes should be independent or nearly independent of one another; there should only be a small number of attributes, preferably not more than six because trade-offs become difficult to understand (Phelps et al., 1978); and attributes should be scientifically meaningful and important facts should not be omitted (Yoo et al., 2008). The type of fuel used to keep the moderate temperature and the structure of houses were considered at a first stage. As they were not directly related with energy-saving measures and consumers did not pay much attention to those attributes at the pretest, the attributes were discarded after consultation with experts. The chosen attributes are explained in Table 1.

The first attribute is the window, which generally consist of a frame, sash, and glazing. The glazing (usually glass) fits into the sash, which in turn is held in place on the wall by the frame. The insulating value of an entire window can be very different from that of the glazing alone. The materials and thickness of glazing make windows more energy-efficient. Thus, the level of attribute is the type of glazing of windows. Double glazing is the glazing process in which a window is formed by two panes of glass with a space between the panes. The space between the glasses is usually several millimeters thick. Air is trapped between the panes of glass and forms a layer of insulation. System glazing is a functional glazing, which is made of special materials and whose thickness is over 22 mm. Double-sash systems are composed of two layers of sash. In this study, 16 mm double glazing and 22 mm system glazing are used for double-sash systems.

The second attribute is the façade. Korea experiences large changes in temperature from season to season. However, human comfort demands a constant temperature in homes and work places throughout the year. In cold weather, it means preventing the escape of heat to the outdoors. In hot weather, it means blocking the invasion of heat from the outdoors. Insulation helps maintaining human comfort by blocking heat flow. Insulation also allows home to be more energy-efficient by reducing the need to rely on artificial heating or cooling devices.

The third attribute is the ventilation. An air cleaner is equipped for fresh air, but it also helps saving air-conditioning energy. In summer, it prevents from using air-conditioning energy used to cool down hot air flowed in during ventilation. Also in winter, by decreasing the necessity of frequent ventilation, energy for heating is saved.

The final attribute is the price, which includes the additional cost of the interior per 1 Pyeong (=3.3 m²) for energy-saving measures of housing, which are likely to be familiar items to respondents in general. The lowest bound of this attribute is 80,000 Korean won (KRW), and the highest bound of this attribute

is KRW 400,000 if the respondent wants the additional energy-saving measures.

A significant feature of the previous, similar study by Banfi et al. (2008) in Switzerland is that the experiment was designed in such a way that each alternative consisted of an upgrade in some attributes and/or a downgrade in other (including negative levels for the price attributes). The purpose was to reflect a more real-world choice thinking of respondents already living in houses with some of the proposed energy-efficiency upgrades. This made as well possible to compare the willingness to pay of people with experience of additional comfort benefits of energy-efficiency equipment at home with those who don't. In this study, we have considered such possibilities. As every households have various situations and environment, there may be some distortion in deriving a true WTP. To reduce this kind of possibility, we assumed that the respondents are going to purchase a new house and the attributes of the house would be improved.

### 2.2. Choice sets

In the questions of the CE, there were three alternatives of which two represented the improved energy-saving measures and the other represented the fixed status quo.[3] Then, there were $4 \times 3^2 \times 2 \times 4 \times 3^2 \times 2$ possible combinations of attributes and levels to form the choice sets. However, it was impractical to ask respondents to choose from all the combinations. Thus, this study employed the orthogonal main effects design that is effective in terms of isolating the effects of individual attributes on the choice (Hanley et al., 1998). With the help of SPSS 12.0 package, we could draw eight choice sets. They were then divided into two sets of four choices each. Each respondent was presented with four choice sets and was asked to choose among the status quo and two alternatives.

### 2.3. Survey area and method

The study area of this research covers seven nationwide metropolitan areas (Seoul, Pusan, Incheon, Daejeon, Daegu,

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[3] As pointed out by an anonymous reviewer, the phrasing of the status-quo alternative should be done in a way that reflects in a realistic way how things will develop if no action is taken. In that way, Soini and Horne (2005) propose the use of the wording "changes will occur as so far" (i.e., some changes will happen in every case) in their analysis of the demand for compensation of non-industrial private forest owners in Finland. In the case of residential energy efficiency in Korea, this might be important if, for instance, respondents were aware at the time of the survey of any Governmental initiative to improve the energy performance of the sector through legislation or economic incentives. Thus, the choice tasks and results in the survey need to be revised from this perspective.